International Journal for Innovative
Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

COPY RIGHT

ELSEVIER
SSRN

IJIEMR Transactions, online available on 19th Jan 2020. Link
:http://www.ijiemr.org/downloads.php?vol=Volume-09&issue=ISSUE-01

Title: **PV SYSTEM FOR FUEL CELL POWERED UPS WITH REDUCED RIPPLE CONTENT BY EMPLOYING FUZZY CONTROLLER**

Volume 09, Issue 01, Pages: 37-45.

Paper Authors

DORAPALLI KALPANA, MR. T.KRANTI KUMAR
Avanthi Institute of Engineering and Technology, Hyderabad, TS, India

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

PV SYSTEM FOR FUEL CELL POWERED UPS WITH REDUCED RIPPLE CONTENT BY EMPLOYING FUZZY CONTROLLER

DORAPALLI KALPANA[1], MR. T.KRANTI KUMAR[2]
[1]PG Scholar, Department of EEE (Electrical Power Systems), Avanthi Institute of Engineering and Technology, Hyderabad, TS, India.
[2]Assistant Professor, Department of EEE, Avanthi Institute of Engineering and Technology, Hyderabad, TS, India
dskalpana3@gmail.com

ABSTRACT

The main objective of this project is renewable energy system for fuel cell powered uninterruptable power supply with reduced ripple content by employing fuzzy controller. This paper has reviewed the root causes of fuel cells' reliability concerns when it is utilized to power single-phase UPS applications. The analysis reveals how the low-frequency current ripples could negatively impact the fuel cells as a dc source. Any failure in fuel cell source is compensated with a renewable energy system to maintain the continuity of supply. The proposed control method also introduces an interleaved pulse-width modulation to further reduce the switching frequency ripple in the dc current. The stability of the proposed control system is stringently examined. Any failure in fuel cell source is compensated with a renewable energy system to maintain the continuity of supply. The RES is selected depending on fuel cell stack power capability. The modelling of the proposed converter with fuzzy controller is done in MATLAB Simulink environment.

I.INTRODUCTION

Fuel cell powered single-phase uninterruptible power supplies (UPS) are commonly adopted to provide high quality and reliable power for system sensitive loads in case of power failures. However, a well-known issue with such single-phase systems is that the performance of dc side may be affected by the second-order current ripple, which is resulted from the double-line frequency component of ac-side instantaneous power. Notably, this low-order current ripple is proved to have measurable effects on fuel cell's inner chemical reactions, and hence, detrimental to fuel cell's reliability and lifespan. In studying interactions between fuel cells and power converters, [1] examines the fuel cell voltage responses to a series of current sinusoidal perturbations and detected an observable hysteresis at around 100 Hz exclusively. Another paper explores the effects of current ripple on fuel cell's performance [2], the result confirms both the presence of hysteric phenomenon and the proximity of ripple frequency to the fuel cell’s cutoff frequency can be factored into additional losses of the output power. Moreover, fuel cell’s durability and lifespan can also be crippled as a result of the low-frequency sinusoidal disturbances [3]–[5]. Besides, the low-frequency current ripples are recently found to be a major cause of degradation in the fuel cell’s cathode catalyst [6], which is another threat to system performance and reliability. Similar effects are also noticeable in battery-powered systems [7]. Despite already serious concerns induced by second-order current ripple, this issue tends to aggravate when the UPS is exposed to nonlinear loads, where the dc input current is polluted by multiple low-frequency ripple components. Apart from disastrous effects on fuel cells, the existence of these current ripples may cause reduced conversion efficiency, nuisance tripping [8] and distorted output voltage in the UPS system. As a result, UPS would provide unreliable and low-quality power to its loads, disrupting normal operations.

In order to mitigate low-frequency current ripples in the dc side of the single-phase system, a variety of methods have been proposed. Depending on their targeted system segments, they can be broadly classified into hardware and software power decoupling techniques. Hardware power decoupling techniques can be further broken down into PPD and APD. The PPD technique is normally implemented by using energy storage devices to decouple the power oscillation [9]. The most widelyused PPD is to increase the intermediate dc-link capacitor [10].

However, the elevated capacitance may prompt the utilization of E-Cap, giving rise to reduced power density and shortened operation lifetime. In contrast, APD, which leverages an organic combination of auxiliary circuits and film capacitor of much lower capacitance to substitute bulky E-Cap, seems to be a promising alternative. The simplest APD method involves inserting an *LC* circuit to the dc bus [11], making large ECap unnecessary. Nonetheless, this technique introduces inductor as another energy storage, which has lower energy density and higher ESR compared to film capacitor [12]. Another approach is to install a bidirectional dc–dc converter in parallel with dc bus and make the ripple power solely supplied by this additional converter [13], [14]. However, the extra circuits lead to increased power loss, system complexity and costs. Other shunt film-capacitor based APD techniques are provided in [12], [15]–[17], and they can be generally categorized into dc decoupling and ac decoupling based on the polarity of the decoupling capacitor voltage [9]. However, their common defects from efficiency and system complexity points of view still remain unresolved. Even in the case of [18], where the decoupling circuit shares switches with the full-bridge inverter, making the number of switches remains the same. Yet, the dc voltage requirement for this topology is doubled [8].

In contrast, software power decoupling, which leverages control schemes to force current ripples to be assimilated solely by capacitors with admissible capacitance, seems to be a better choice as it requires no additional hardware. One of the most common approaches is to incorporate an inner inductor current loop in addition to the existing voltage loop, forming a dual-loop control scheme [19]. However, the effective current ripple suppression is realized at the expense of the significantly reduced voltage loop crossover frequency [20].An ameliorated approach is to insert a notch filter with its characteristic frequency tuned at current ripple's frequency into the voltage loop [21], through which, the gain of voltage controller at the targeted frequency is successfully decreased without causing a low-voltage loop crossover frequency. Another literature attempts to balance the current ripple reduction effect and dynamic response by tuning the output impedance of the power converter [20]. A modified dc bus voltage reference created by adding the second-harmonic component of load current through feed forward loop is discussed in [22]. And a similar approach involves incorporating the desired second-harmonic voltage fluctuation to the dc voltage reference [23]. By having the modified dc bus voltage reference tracked by the control loop, the second-harmonic current is well suppressed in both cases. Nevertheless, all these methods may require two-stage power conversion, which implies that a bulky dc bus capacitor is needed to ensure the normal operation of the dc-ac conversion.

In view of the design challenges mentioned earlier, a differential inverter composed by two identical bi-directional dc–dc boost converters is proposed in [24] and its topology is shown in Fig. 1. Instead of having a large dc-bus capacitor to buffer the double-line frequency power, this topology removes the dc input current ripple by regulating the voltage waveforms of the two output capacitors. However, in [24], the voltage references of the power decoupling capacitors are calculated in an open-loop manner, which limits its working scope to linear and constant load. A rule-based control is introduced in [25] to reduce the second-order harmonic current in all power operating quadrants. However, like its predecessor, this method is unable to handle nonlinear load. Despite [26] reported an ameliorated closed-loop waveform control that enables the system to work under load variations, the ac voltage output from this method is noticeably distorted when it is utilized to supply nonlinear load.

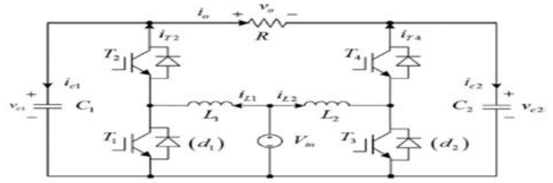


Fig. 1. Topology of the boost inverter for UPS applications

II.EXISTING SYSTEM

A well-known issue of fuel-cell-powered single-phase uninterruptible power supplies (UPS) is that the input current from the dc source is coupled with the second-order current ripple due to the ac-side instantaneous power pulsating at twice the line frequency. The low-frequency ripple component has been confirmed to have detrimental impacts on fuel cell's reliability and lifespan. To solve this issue, a boost inverter that can work in both differential mode (DM) and common mode (CM) operations is adopted by this paper. The DM operation achieves active power conversion and a well-regulated ac output voltage. Meanwhile, the CM operation ensures effective dc current ripple reduction. In addition to operating with linear loads, the proposed control method extends its working scope to nonlinear loads, where meticulously designed repetitive controllers are employed to handle the multiple low-harmonic situations.

III. PROPOSED SYSTEM

The proposed control method also introduces an interleaved pulse-width modulation to further reduce the switching frequency ripple in the dc current. The stability of the proposed control system is stringently examined. Any failure in fuel cell source is compensated with a renewable energy system to maintain the continuity of supply. The RES is selected depending on fuel cell stack power capability. The modelling of the proposed converter with FUZZY controller is done in MATLAB Simulink environment. In the light of all the aforementioned concerns, this paper adopts the inverter topology shown in Fig. 1 for the fuel cell with pv cell powered single-phase UPS system as presented in Fig. 2. A unique feature of this topology is that it can essentially work in dual-mode operations. The differential mode (DM) operation realizes active power conversion and ac output voltage regulation, while the common mode (CM) operation mitigates ripple component in the dc current. Notably, the proposed current ripple reduction method can work under both linear and nonlinear load, which has never been studied under this application before.

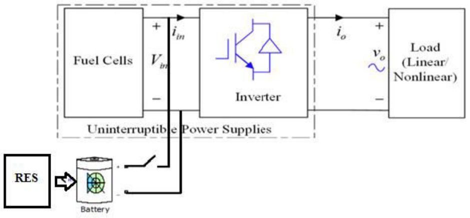


Fig. 2. System block diagram of fuel-cell-powered single-phase UPS.

IV PROPOSED SYSTEM CONTROLLER DESIGN

Instead of controlling each operation mode through separate loops, this paper proposes a comprehensive control scheme composed by three sub-control block diagrams as shown in Fig. 3 Clearly, DM-oriented control scheme is designed to ensure a harmonic free ac output voltage regardless of the types of load it supplies. The CM-oriented control scheme aims at dc offset voltage regulation and input current ripple reduction. In order to present readers an elaborative view over the rationales behind the control schemes design, three sub-control block diagrams will be temporarily disassembled in the following analysis.

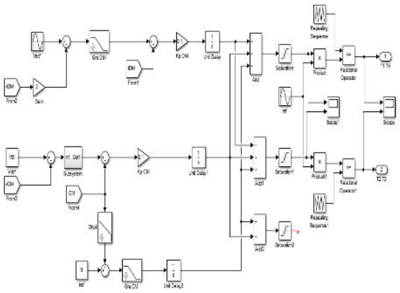


Fig. 3 Overall control block diagram for the boost inverter.

The classic dual-loop control structure is employed for the boost inverter under DM operation, the implementation of which is presented in Fig. 4 Notably, in order to maximally approximate the control model to the real system, all functions are presented in their z-domain forms. For the inner current regulation loop, z-1corresponds to the one-sampled computation delay in the digital control system, while a half-sampled PWM delay derived through zero order hold method is included during continuous-discreet conversion. Furthermore, a proportional gain *Kp* DM is introduced to neutralize the *LC* resonance. *Gd*2*i* DM(*s*) and *Gi*2*v* DM(*s*) represent plant models, whose transfer functions are respectively given in (11) and (12). As for the outer voltage regulation loop, a FUZZY controller is normally adopted to mitigate the harmonics of interest, when only linear loads are concerned. However, in the case that the nonlinear loads are also supplied by the UPS, the ac output voltage may be severely distorted by the imposition of the low frequency odd-order harmonics, e.g., third, fifth, seventh, etc., leading to system malfunction. Under such scenario, multiple

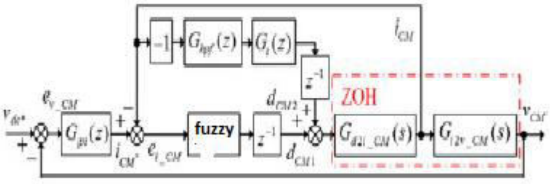


Fig. 4 Closed-loop control for ac voltage regulation (DM operation).

Hence, both mathematic deduction and experimental results in [24] have revealed that the successful suppression of harmonic at one specific order may give rise to the harmonic in the next periodical order, i.e., second order and fourth order in [24].

Therefore, it is extremely difficult to predict the exact number resonant controllers that are adequate to combat the constantly newborn harmonics. In light of the FUZZY controller's ineffectiveness to deal with multiple low-frequency harmonic situation, a modified plug-in repetitive controller is introduced in this paper as Grc DM(z), and its control block diagram is given in Fig. 4.

The negative feedback repetitive controller in Fig.4 provides high gains at odd-order harmonic frequencies, which can theoretically suppress all odd-order harmonics below the Nyquist frequency. N denotes the number of delayed samplings, which equals the sampling frequency fs divided by the fundamental frequency fn . Since only odd-order harmonic frequencies are concerned in DM operation, N/2 delays are adequate in this design [28]. Thanks to this particular character, tracking errors may converge to zero in a half fundamental cycle basis, showing a superior dynamic response to that of a conventional plug-in repetitive controller. In addition, Kr1 is the repetitive control gain and is selected properly to achieve plausible damping effect and fast transient response [29]. Q(z) is a zero-phase-shift low-pass filter featured in a unity gain at low frequencies, whose equation is given in (17). The inclusion of such low-pass filter ensures graduate magnitude response attenuation as frequency increases, which strengthens the stability margin of the system.

To further enhance the system stability, a carefully designed phase lead term zm1 is embedded in the forward path to compensate the phase delay caused by the feedback control system, digital computation, and PWM process [29]. Guided by the design procedures prescribed in [29], m1 = 5 is found to have an excellent compensation effect for the DM voltage regulation loop, which is also verified by the system's Nyquist locus in MATLAB as elaborated in the next section. Finally, the transfer function of the modified repetitive controller is given in (18)

$$Q(z) = \frac{z + 2 + z^{-1}}{4} \qquad (17)$$

$$G_{\mathrm{rc\_DM}}(z) = K_{r1} \frac{Q(z)\, z^{-\frac{N}{2}+m_1}}{1 + Q(z)\, z^{-\frac{N}{2}}}. \qquad (18)$$

B. CM Control Scheme Design

Different from the implementation of DM operation control scheme, the Control design incorporates two correlated control block diagrams as shown in Figs. 5 and 6, primarily because two functions are fulfilled by the operation. One of the functions is to regulate the dc offset voltages of the output capacitors in order to guarantee that the boost converters are working well within the linear modulation range

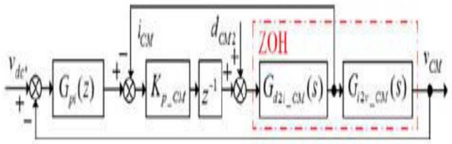


Fig.5 Closed-loop control for dc offset voltage regulation (CM operation).

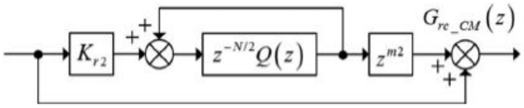


Fig.6 Plug-in repetitive controller for even-order harmonics reduction.

For the dc offset voltage regulation control block diagram as shown in Fig. 5, the inner current loop configuration is nearly the same as its DM current regulation counterpart due to the resemblance of their plant models. Notably, a dCM2 which denotes the duty cycle output by control III in Fig. 5 is added before a full dCM signal is assembled and sent to the next block. The outer voltage loop is well attended by simply using a proportional-integral controller Gpi(z) since only the dc component is concerned. Gd2i

CM(s) and Gi2v CM(s) are plant models, whose transfer functions are in given in (15) and (16).

SIMULATION RESULTS

A) EXISTING RESULTS

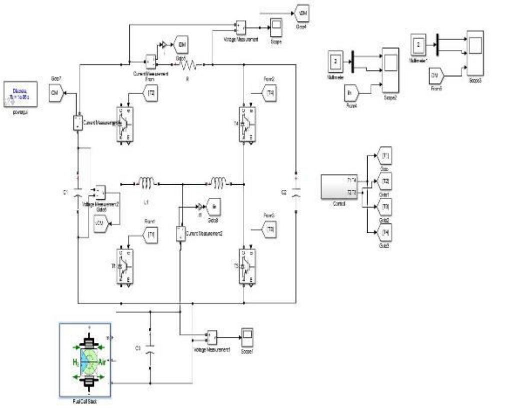


Fig 7 MATLAB/SIMULINK diagram of fuel-cell-powered single-phase UPS.

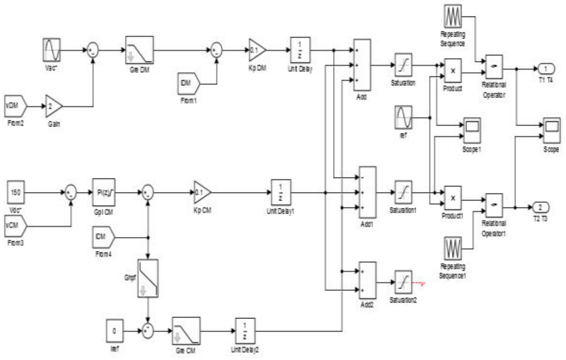


Fig.8 Controller subsytem

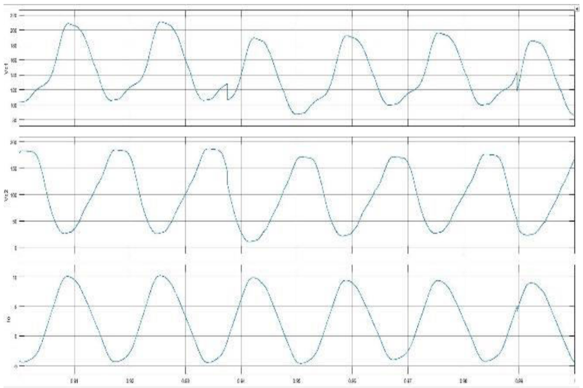


Fig.9 Vdc1,Vdc2 and Idm (load current)

B) EXTENSION RESULTS

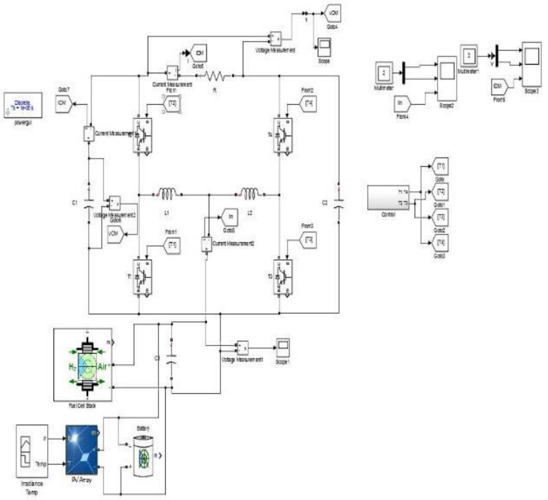


Fig.10 MATLAB/SIMULINK diagram of proposed PV with fuel-cell-powered single-phase UPS.

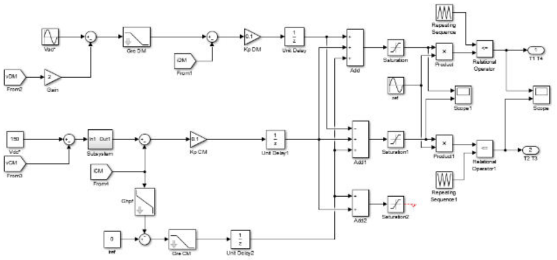


Fig.11 Propoased Controller subsystem

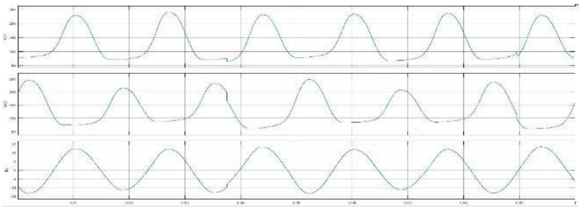
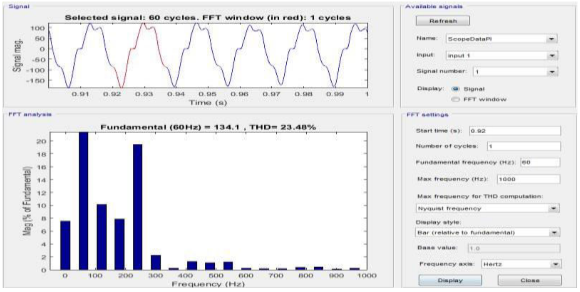


Fig.12 Vdc1,Vdc2 and Idm (load current)



Signal

Selected signal: 60 cycles. FFT window (in red): 1 cycles

FFT analysis

Fundamental (60Hz) = 134.1 , THD= 23.48%

Available signals

Name: ScopeDataPI

Input: input 1

Signal number: 1

Display: ● Signal ○ FFT window

FFT settings

Start time (s): 0.92

Number of cycles: 1

Fundamental frequency (Hz): 60

Max frequency (Hz): 1000

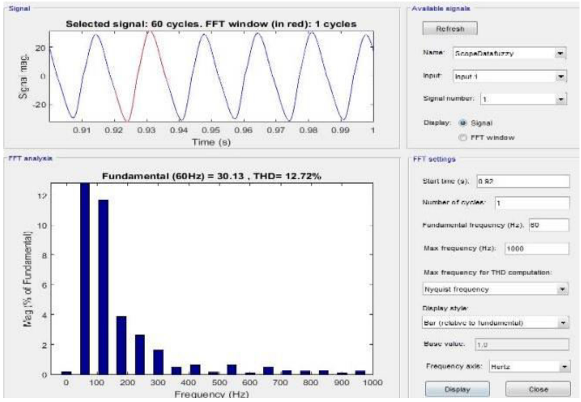
Max frequency for THD computation: Nyquist frequency

Display style: Bar (relative to fundamental)

Base value: 1.0

Frequency axis: Hertz

Fig.13 THD of Load current with existing controller



Name: ScopeDatafuzzy
Input: Input 1
Signal number: 1
Display: ● Signal ○ FFT window
Start time (s): 0.82
Number of cycles: 1
Fundamental frequency (Hz): 60
Max frequency (Hz): 1000
Max frequency for THD computation: Nyquist frequency
Display style: Bar (relative to fundamental)
Base value: 1.0
Frequency axis: Hertz

Fig.14 THD of load current with Proposed fuzzy controller

CONCLUSION

This project proposes renewable energy system (pv cell) with fuel cell powered uninterruptable power supply with reduced ripple content by employing FUZZY controller. fuel cells' reliability concerns when it is utilized to power single-phase UPS applications. The analysis reveals how the low-frequency current ripples could negatively impact the fuel cells as a dc source. To conquer the reliability-oriented challenge, a dual-mode operated boost inverter with meticulously designed control scheme is presented in this paper. The proposed control method also introduces an interleaved pulse-width modulation to further reduce the switching frequency ripple in the dc current. The stability of the proposed control system is stringently examined. Any failure occurs in fuel cell the renewable energy system to maintain the continuity of supply to the inverter. Compared to the existing system proposed system reduces load current THD. The modelling of the proposed converter with FUZZY controller is done in MATLAB Simulink environment.

REFERENCES

[1] G. Fontes, C. Turpin, S. Astier, and T. A. Meynard, "Interactions between fuel cells and power converters: Influence of current harmonics on a fuel cell stack," IEEE Trans. Power Electron., vol. 22, no. 2, pp. 670–678, Mar. 2007.

[2] R. Ferrero, M. Marracci, and B. Tellini, "Single PEM fuel cell analysis for the evaluation of current ripple effects," IEEE Trans. Instrum. Meas., vol. 62, no. 5, pp. 1058–1064, May 2013.

[3] W. Choi, P. Enjeti, J. W. Howze, and G. Joung, "An experimental evaluation of the effects of ripple current generated by the power conditioning stage on a proton exchange membrane fuel cell stack," J. Mater. Eng. performance, vol. 13, pp. 257–264, 2004.

[4] R. S. Gemmen, "Analysis for the effect of inverter ripple current on fuel cell operating condition," J. Fluids Eng., vol. 125, pp. 576–585, 2003.

[5] B. Wahdame et al., "Impact of power converter current ripple on the durability of a fuel cell stack," in Proc. IEEE Int. Symp. Ind. Electron., 2008, pp. 1495–1500.

[6] F. Sergi et al., "PEM fuel cells analysis for grid connected applications," Int. J. Hydrogen Energy, vol. 36, pp. 10908–10916, 2011.

[7] S. Bala, T. Tengn´er, P. Rosenfeld, and F. Delince, "The effect of low frequency current ripple on the performance of a Lithium Iron Phosphate (LFP) battery energy storage system," in Proc. IEEE

Energy Convers. Congr. Expo., 2012, pp. 3485–3492.

[8] Y. Tang, W. Yao, and F. Blaabjerg, "A dual mode operated boost inverter and its control strategy for ripple current reduction in single-phase uninterruptible power supplies," in Proc. 9th Int. Conf. Power Electron. ECCE
Asia, 2015, pp. 2227–2234.

[9] Z. Qin, Y. Tang, P. C. Loh, and F. Blaabjerg, "Benchmark of AC and DC active power decoupling circuits for second-order harmonic mitigation in kilowatt-scale single-phase inverters," IEEE J. Emerging Sel. Topics Power Electron., vol. 4, no. 1, pp. 15–25, Mar. 2016.

[10] M. E. Schenck, L. Jih-Sheng, and K. Stanton, "Fuel cell and power conditioning system interactions," in Proc. 20th Annu. IEEE Appl. Power Electron. Conf. Expo., 2005, vol. 1, pp. 114–120.

[11] K. Fukushima, I. Norigoe, M. Shoyama, T. Ninomiya, Y. Harada, and K. Tsukakoshi, "Input current-ripple consideration for the pulse-link DC-AC converter for fuel cells by small series LC circuit," in Proc. 24th Annu. IEEE Appl. Power Electron. Conf. Expo., 2009, pp. 447–451.

[12] Y. Tang, Z. Qin, F. Blaabjerg, and P. C. Loh, "A dual voltage control strategy for single-phase PWM converters with power decoupling function," IEEE Trans. Power Electron., vol. 30, no. 12, pp. 7060–7071, Dec. 2015.

[13] R. J. Wai and C. Y. Lin, "Active low-frequency ripple control for cleanenergy power-conditioning mechanism," IEEE Trans. Ind. Electron., vol. 57, no. 11, pp. 3780–3792, Nov. 2010.

[14] R. J. Wai and C. Y. Lin, "Dual active low-frequency ripple control for clean-energy power-conditioning mechanism," IEEE Trans. Ind. Electron., vol. 58, no. 11, pp. 5172–5185, Nov. 2011.

[15] H. Li, K. Zhang, H. Zhao, S. Fan, and J. Xiong, "Active power decoupling for high-power single-phase PWM rectifiers," IEEE Trans. Power Electron., vol. 28, no. 3, pp. 1308–1319, Mar. 2013.